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(ICS 91.160.10)

CODE OF PRACTICE FOR

Illumination in industrial premises

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Foreword

This Singapore Standard was prepared by a Working Group appointed by the Technical Committee on General Safety under the direction of the Industrial Safety Standards Committee.

Optimum visual performance of persons in indoor industrial premises is the focus of this code. Suitable and adequate lighting is essential for the safety, comfort, well-being and productivity of the persons working in such premises. This code provides the guidelines for lighting requirements in terms of quantity and quality of illumination, lighting systems and lighting measurement, maintenance and improvement of such customised lighting systems for various indoor industrial situations.

Ease of implementation is emphasised in this code. Maintenance illuminance is recommended for different types of industrial areas, tasks and processes. This represents the minimum average illuminance, which needs to be maintained at all times throughout the life of the lighting system.

This code can be viewed as a complementary document to SS CP 38 : 1999 (Artificial lighting in buildings). This code deals with the provision of lighting for optimum visual performance in indoor industrial premises in particular, while SS CP 38 covers also other applications.

In preparing this code, reference was made to the following publications:

1.	AS 1680.1 : 1990	Interior lighting – General principles and recommendations
2.	AS/NZS 1680.2.4 : 1997	Interior lighting – Industrial tasks and processes
3.	ANSI/IES-RP-7 : 1983	Industrial lighting
4.	CIBSE Code	Code for interior lighting, 1994
5.	ISO 8995 : 1989	Principles of visual ergonomics – The lighting of indoor work systems
6.	SS CP 38 : 1999	Code of practice for artificial lighting in buildings

NOTE

1. *Singapore Standards are subject to periodic review to keep abreast of technological changes and new technical developments. The revisions of Singapore Standards are announced through the issue of either amendment slips or revised editions.*

2. *Compliance with a Singapore Standard does not exempt users from legal obligations.*

Code of practice for illumination in industrial premises

0 Introduction

The purpose of industrial lighting is to provide energy efficient illumination in quality and quantity sufficient for safety and to enhance visibility and productivity within a working environment. It is essential to understand the task, the environment and the lighting and their interrelationships. To these ends, the following should be considered in any lighting design:

a) design lighting for expected activity (light for seeing tasks with less light in surrounding non-working areas);

b) design and use more effective luminaires;

c) use light source with the highest practicable efficiency (high lumens per watt output);

d) use recessed luminaires if appropriate in clean rooms and other industrial interiors where either air supply or air return (or both) luminaires functions may be desirable. Ventilated and heat-dissipating luminaires may increase light output, decrease dirt collection on reflecting surfaces of luminaires, or improve ballast life;

e) use the lightest appropriate finish on ceilings, walls, floor and equipment;

f) determine the need for high colour rendering sources;

g) provide appropriate controls to permit turning off lights when not needed;

h) determine the accessibility of luminaires for maintenance;

i) make use of daylighting as is feasible;

j) keep lighting equipment clean and in good working condition; and

k) provide instructions covering operation and maintenance of lighting equipment.

1 Scope

This code provides guidelines on the provision of adequate lighting for optimum visual performance in indoor industrial premises. It covers the quality and quantity aspects of lighting, lighting systems and measurement, maintenance and improvement of the lighting systems to ensure safety, comfort, well-being and productivity of persons working in such premises. Ease of implementation is emphasised. Maintenance illuminance is recommended for different types of industrial areas, tasks and processes. This represents the minimum average illuminance, which needs to be maintained at all times throughout the life of the lighting system.

2 Definitions

2.1 Adaptation

The process which takes place as the visual system adjusts itself to the brightness or the colour of the visual field. The term is also used, usually qualified, to denote the final state of this process. For

example 'dark adaptation' denotes the state of the visual system when it has become adapted to a very low luminance.

2.2 Apparent colour

It is the colour of a light source; subjectively the hue of the source or of a white surface illuminated by the source; the degree of warmth associated with the source colour. Lamps of low correlated colour temperatures are usually described as having a warm apparent colour, and lamps of high correlated colour temperature as having a cold apparent colour.

2.3 Average illuminance

The arithmetic mean of the illuminances within a room or over a task area measured in accordance with the procedure mentioned in Clause 6 of this code.

2.4 Brightness

Attribute of the visual sensation associated with the amount of light emitted from a given area. It is the subjective correlate of luminance.

2.5 Candela (cd)

The SI unit of luminous intensity, equal to one lumen per steradian.

2.6 Colour rendering

A general expression for the appearance of surface colours when illuminated by light from a given source compared, consciously or unconsciously, with their appearance under light from some reference source. 'Good colour rendering' implies similarity of appearance to that under an acceptable light source, such as daylight.

2.7 Colour rendering index (CRI)

A measure of the degree to which the colours of surfaces illuminated by a given light source conform to those of the same surfaces under a reference illuminant, suitable allowance having been made for the state of chromatic adaptation.

2.8 Colour temperature (K)

The temperature of a full radiator which emits radiation of the same chromaticity as the radiator being considered.

2.9 Contrast

A term that is used subjectively and objectively. Subjectively it describes the difference in appearance of two parts of a visual field seen simultaneously or successively. The difference may be one of brightness or colour or both. Objectively, the term expresses the luminance difference between the two parts of the field by such relationships as:

$$\text{Contrast} = \frac{L - L_1}{L_1}$$

Quantitatively, the sign of the contrast is ignored. L_1 is the dominant or background luminance. L is the task luminance.

2.10 Correlated colour temperature (unit: K)

The temperature of a full radiator which emits radiation having a chromaticity nearest to that of the light source being considered, e.g., the colour of a full radiator at 3500K is the nearest match to that of a white tubular fluorescent lamp.

2.11 Diffuse reflection

Reflection in which the reflected light is diffused and there is no significant specular reflection, as from a matt paint.

2.12 Diffused lighting

Lighting in which the luminous flux comes from many directions, none of which predominates.

2.13 Direct lighting

Lighting in which the greater part of the luminous flux from the luminaires reaches the surface (usually the working plane) directly, i.e. without reflection from surrounding surfaces. Luminaires with a flux fraction ratio less than 0.1 are usually regarded as direct.

2.14 Directional lighting

Lighting designed to illuminate a task or surface predominantly from certain directions.

2.15 Disability glare

Glare which impairs the ability to see details.

2.16 Discharge lamp

A lamp in which the light is produced either directly or by the excitation of phosphors by an electric discharge through a gas, a metal vapour or a mixture of several gases and vapours.

2.17 Discomfort glare

Glare which causes visual discomfort.

2.18 Downlighters

Luminaires from which light is emitted only within relatively small angles to the downward vertical.

2.19 Emergency lighting

Lighting provided for use when the main lighting installation fails.

2.20 Escape lighting

Emergency lighting provided to ensure that the means of escape can be safely and effectively used at all material times.

2.21 Flicker

A visible oscillation in luminous flux.

2.22 Flux fraction

The proportion of the luminous flux emitted from a luminaire in the upper or lower hemisphere (upper and lower flux fraction).

2.23 Flux fraction ratio

The ratio of the upward luminous flux to the downward luminous flux from a luminaire. It is also the ratio of the upper flux fraction to the lower flux fraction and the ratio of the upward light output ratio to the downward light output ratio.

2.24 Full radiator

A thermal radiator obeying Planck's radiation law and having the maximum possible radiant exitance for all wavelengths for a given temperature; also called a black body to emphasize its absorption of all incident radiation.

2.25 General lighting

Lighting designed to illuminate the whole of an area uniformly, without provision for special local requirements.

2.26 General surround lighting

Lighting designed to illuminate the non-working parts of a working interior.

2.27 Glare

The discomfort or impairment of vision experienced when parts of the visual field are excessively bright in relation to the general surroundings.

2.28 Glare index system

A system which produces a numerical index calculated according to the method described in CIBSE Technical Memorandum 10. It enables the discomfort glare from lighting installations to be ranked in order of severity and the permissible limit of discomfort glare from an installation to be prescribed quantitatively.

2.29 Hazardous environment

An environment in which a risk of fire or explosion exists.

2.30 Hostile environment

An environment in which the lighting equipment may be subject to chemical, thermal or mechanical attack.

2.31 Illuminance (E) (unit: lm/m^2, lux)

The luminous flux density at a surface, i.e. the luminous flux incident per unit area. This quantity was formerly known as the illumination value or illumination level.

2.32 Illumination

The process of lighting.

2.33 Incandescent lamp

A lamp in which light is produced by a filament heated to incandescence by the passage of an electric current.

2.34 Indirect lighting

Lighting in which the greater part of the flux reaches the surface (usually the working plane) only after reflection at other surfaces and particularly at the roof or ceiling. Luminaires with a flux fraction ratio greater than 10 are usually regarded as indirect.

2.35 Initial illuminance

The value of average illuminance which is initially provided by the lighting system, i.e. with new lamps (aged to 100 h), clean luminaires and room surfaces.

2.36 Initial light output (unit: lm)

The luminous flux from a lamp after 100 h of operation.

2.37 Local lighting

Lighting designed to illuminate a particular small area which usually does not extend far beyond the visual task, e.g. a desk light.

2.38 Localised lighting

Lighting designed to illuminate an interior and at the same time to provide higher illuminances over a particular part or parts of the interior.

2.39 Lumen (lm)

The SI unit of luminous flux, used in describing a quantity of light emitted by a source or received by a surface. A small source which has a uniform luminous intensity of one candela emits a total of 4π lumens in all directions and emits one lumen within unit solid angle.

2.40 Luminaire

An apparatus which controls the distribution of light given by a lamp or lamps and which includes all the components necessary for fixing and protecting the lamps and for connecting them to the supply circuit. Luminaire has superseded the term lighting fitting.

2.41 Luminance (L) (unit: cd/m^2)

The physical measure of the stimulus which produces the sensation of brightness measured by the luminous intensity of the light emitted or reflected in a given direction from a surface element, divided by the area of the element in the same direction. The SI unit of luminance is the candela per square metre, the relationship between luminance and illuminance is given by the equation:

$$\text{Luminance} = \text{illuminance} \times \text{reflectance factor} / \pi$$

This equation applies to a matt surface. For a non matt surface, the reflectance factor is replaced by the luminance factor.

2.42 Luminance factor (*B*)

The ratio of the luminance of a reflecting surface, viewed in a given direction, to that of a perfect white uniform diffusing surface identically illuminated.

For a non-matt surface the luminance factor may be greater or less than the reflectance.

2.43 Luminous flux (unit: lm)

The light emitted by a source, or received by a surface. The quantity is derived from radiant flux by evaluating the radiation in accordance with the spectral sensitivity of the standard eye as described by the CIE Standard Photometric Observer.

2.44 Luminous intensity (unit: cd)

A quantity which describes the power of a source or illuminated surface to emit light in a given direction. It is the luminous flux emitted in a very narrow cone containing the given direction divided by the solid angle of the cone: the result is expressed in candelas.

2.45 Lux (*lx*)

The SI unit of illuminance, equal to one lumen per square metre.

2.46 Maintenance factor (*MF*)

The ratio of the illuminance provided by an installation in the average condition of dirtiness and lamp lumen depreciation expected in service, to the illuminance from the same installation when clean and with new lamp(s). The maintenance factor is always less than unity.

2.47 Maintenance illuminance

The value of average illuminance below which it is necessary to take remedial action in terms of maintaining the lighting system, e.g. by replacing the lamps or by cleaning the luminaires, windows, rooflights and room surfaces.

2.48 Metamerism

The phenomenon occurring when coloured objects which match under one illuminant do not match under another (object metamerism) or when illuminants of the same apparent colour do not have the same colour rendering properties (illuminant metamerism).

2.49 Mixed reflection

Partly specular and partly diffused reflection, as from a smooth, glossy paint.

2.50 Reflectance (*R*)

The ratio of the luminous flux reflected from a surface to the luminous flux incident on it. Except for matt surfaces, reflectance depends on how the surface is illuminated but especially on the direction of the incident light and its spectral distribution. The value is always less than unity and is expressed as either a decimal or as a percentage.

2.51 Specular reflection

Reflection without diffusion in accordance with the laws of optical reflection as in a mirror.

2.52 Standby lighting

Emergency lighting provided to enable normal activities to continue.

2.53 Stroboscopic effect

An illusion caused by oscillation in luminous flux, that makes a moving object appear as stationary or as moving in a manner different from that in which it is truly moving.

2.54 Task area

The area within which the task is located. This may be the whole of the room or a small part of it.

2.55 Task illuminance

The value of maintenance illuminance which is recommended for a specific visual task.

2.56 Task surroundings

Surface visible within 45° of the line of sight when looking at details anywhere on the task. The surfaces may be in the same plane as the task or at some distance from it.

Surfaces within 15° of the line of sight are referred to as the 'immediate task surroundings'. The actual size and shape of the task surroundings will depend on the size and shape of the task, the distance of the task from the eye of the observer and from the surfaces(s) against which the task is seen.

2.57 Task detail

The minute portion of the task which is under examination at any given moment.

2.58 Uplighter

Luminaires which direct most of the light upwards onto the ceiling or upper walls in order to illuminate the working plane by reflection.

2.59 Veiling reflections

A term sometimes applied to reflections which reduce task contrast. Pencil marks, for example, become harder to see when they reflect the light source, because the increased luminance causes the black pencil marks to appear pale grey or disappear altogether. Printed matter can be similarly affected.

2.60 Visual acuity

The capacity for discriminating between objects which are very close together. Quantitatively, it can be expressed by the reciprocal of the angular separation in minutes of arc between two lines or points which are just separable by the eye. The expression more commonly used for an individual's visual acuity is the ratio of the distance at which the individual can read a line on a standard optician's chart to the standard distance at which a person with normal sight can read that line (e.g. 6/12 means that the individual can just read at 6 metres the line which a normally sighted person can just read at 12 metres).

2.61 Visual environment

The environment either indoors or outdoors as seen by an observer.

2.62 Visual field

The full extent in space of what can be seen when looking in a given direction.

2.63 Visual task

The visual element of the work being done.

2.64 Working plane

The horizontal, vertical, or inclined plane in which the visual task lies. If no information is available, the working plane may be considered to be horizontal and at 70 cm above the floor for offices, horizontal and 85 cm above the floor for industry.

3 Factors influencing visual tasks

One sees an object and its identifying features by reflection, transmission, and silhouette.

Industrial tasks vary in visual difficulty, from highly visible to barely visible. Factors that affect task visibility include size, contrast, time, and luminance (photometric brightness). They are sufficiently interdependent that compensation for a deficiency in one may be made by augmenting (within limits) one of the others to maintain equal visibility.

As illumination is influenced by many different factors, lighting installations should be designed by a competent person. The factors may be expressed in terms of quality (distribution of illuminance, colour of light, its direction, diffusion, and free from glare) and quantity (amount of illuminance).

3.1 Size, shape and texture

Discrimination of size, form and texture is a complex psycho-physiological process of recognition of the environment. It involves at least three functions: the perception of contrast, the resolution of visual details, and the perception of depth and distance.

Resolution of the visual details can be expressed quantitatively through visual acuity. Visual acuity is a function of the quality of a person's eyesight and of the environmental characteristics and, in particular, the magnitude of the perceived luminance.

Manipulation of size can be an important means of improving visibility. For example, performance can often be improved by enlarging the detail, bringing the object nearer to the viewer or using optical aids.

The perception of depth, relief, and distance depends not only on the occulomotor functions, such as quality of binocular vision, and on intellectual functions, such as memory of size and form of known objects, but also on the interpretation of contextual cues. Perception of texture depends upon the pattern of shadow and light on a surface.

When designing the lighting for a particular task, care shall be taken that directionality and diffusion of the light do not reduce the contrast required for the perception of texture and form of objects by excessive diffusion of the light. Some shadows are often helpful in perception, but other types of shadow may make it more difficult. For example, too many shadows can be confusing and misinterpretation of the shadow pattern is possible.

3.2 Contrast

The perception of an object in its surroundings is mainly dependent on the contrast, in terms of luminance and/or colour, between the object and its background. Whenever possible, tasks and lighting should be designed to optimize contrast.

Within certain limits, as luminance is increased so is the sensitivity of the eye to contrast. Sensitivity is also affected by gradients of the boundaries between the two luminances or colours, but is reduced by too large a variation in luminance and colour within the visual field surrounding the task to be perceived. For example, if a bright source of light is within the field of view, disability glare will cause an apparent reduction in contrast. A reduction can also be caused by looking away from the task towards a more brightly lit area, causing a brief change in the adaptation of the eye (transient adaptation).

Contrast can also be reduced by veiling reflections. This occurs when high luminance is reflected by the task towards the eyes and thus veils, or interferes with, the perception of the task. In particular, reflections of light sources in specular or semi-specular visual tasks can result in substantial losses in contrast. This can be avoided with adequate diffusion of the lighting, for example, by light reflected from the ceiling and/or walls or light directed on the task from the side or behind the person.

3.3 Movement and time available for viewing

The perception of motion requires movement of the image of the target on the retina. The *fovea* of the eye is more sensitive to the perception of movement than is the periphery. The peripheral area of the retina is relatively more sensitive to motion than to form, so the eyeball turns toward the moving target to bring the image into the center of the retina for more detailed inspection.

The accuracy for perception of movement depends on speed, size, form and contrast. Visual perception of an object also depends on the time available for viewing. A brief glance may be suffice if it is a large, high contrast object. A prolonged gaze may be needed if it is not. The visibility of a moving object can be improved by allowing the eye to follow it over an adequate length of its path. If the speed of movement across the visual field is too high or the path is too erratic, or both, visibility deteriorates very rapidly.

3.4 Luminance

Under normal conditions, visual performance increases with illuminance. The visual performance improves rapidly at lower illuminance but flattens off eventually where further increase in illuminance would produce no effect.

The visual performance of tasks of small size and/ or low contrast can be improved by providing high levels of luminance (i.e. by increasing illuminance), but the performance of tasks of large size and high contrast rapidly reaches a maximum at moderate values of luminance.

3.5 Age and subnormal vision

The age of the persons should be considered in illuminance recommendations. Higher illuminance is needed by older persons to compensate for loss in vision due to ageing.

The size of the pupil decreases with age. To achieve a retinal illuminance equal to that of the eyes of younger persons, it is therefore necessary to increase task illuminance.

Accommodation refers to the ability of the eye to focus on an object or to change its focus for one object to another. This is accomplished by increasing or decreasing the refracting power of the eye's crystalline lens. For objects closer to the eye, the thickness of the crystalline lens increases allowing the curvature of the lens to increase. For objects far away from the eye, the thickness of the crystalline lens decreases allowing the curvature of the lens to decrease. Accommodation decreases rapidly with age. By the mid-forties, most individuals can no longer see clearly at normal working distances and may need optical assistance. By the age 60, there is very little accommodation ability remaining in most of the population. The need for optical aids can be delayed in such persons when contrasts are optimized by appropriate lighting design.

Other aspects of visual performance that deteriorate with aging include visual acuity, speed of vision, ability to detect peripheral movements, ability to see under sudden changes of lighting, and resistance to glare.

3.6 Colour

Colour is an attribute of light, which contributes considerably to the general impression of our environment as well as to visual performance. In particular, it is useful for quick and easy identification of objects in the workspace.

Colour perception improves as illuminance increases, within certain limits. Colour perception varies across the retina of the eye. Colour discrimination is at its best in the central area of the retina.

Colour constancy describes the way in which colours are perceived in relationship to each other. The colours of the scene maintain relatively constant relation when illuminated under a spectral composition sufficiently similar to that found in daylight. However, if the spectral composition deviates too much from this, colour constancy is not retained, and the colour appearance of the scene will change. Colour appearance is dependent not only upon the spectral composition of the light, but also upon the characteristics of the surface examined, the luminance, colour contrasts and the state of colour adaptation.

The eye can perceive quite small differences in colour between two adjacent surfaces even if the luminances are identical, but comparison with remembered colours is more difficult. Different light sources can improve or reduce discrimination of certain colours.

However, defects in colour vision occur in some individuals, and this can alter the appearance of colours and the power of discrimination between them, and may be important in some circumstances for certain occupations.

4 Quantity and quality of lighting

4.1 General

The desirable illuminance for a space depends primarily upon the intended use of the space, such as the nature of the seeing tasks, the characteristics of the workers, the importance of speed, and the accuracy in performing the task. These influencing factors have been discussed in Clause 3 above.

Quality of illumination pertains to the distribution of luminance in the visual environment. The term is used in a positive sense and implies that all luminances contribute favourably to visual performance, visual comfort, ease of seeing, safety, and aesthetics. Glare, diffusion, direction, uniformity, colour, luminance, and luminance ratios all have a significant effect on the ability to see easily, accurately, and quickly. Severe seeing tasks (such as discernment of fine details over a long period) require higher quality illumination than those that are casual or of relatively short duration.

Although poor quality lighting is easily recognized as visually uncomfortable and possibly hazardous, moderate deficiencies are not readily detected. The cumulative effect of even slightly glaring conditions can result in material loss of visual efficiency and in fatigue.

4.2 Glare

Glare is the sensation produced by luminance within the visual field that is sufficiently greater than that to which the eyes are adapted. Glare may cause annoyance, discomfort, or loss in visual performance and visibility.

4.2.1 Direct glare

Glare resulting from high luminance or from insufficiently shielded light sources in the field of view is known as direct glare. It is usually associated with bright luminaries, ceilings, and windows that are outside the visual task or area viewed.

Direct glare may be reduced by:

a) decreasing the luminance of light sources or lighting equipment, or both;

b) reducing the area of high luminance causing the glare condition;

c) increasing the angle between the glare source and the line of vision; and

d) increasing the luminance of the area surrounding the glare source and its background.

Unshaded windows are frequent sources of direct glare. They may allow direct view of the sun, bright portions of the sky or bright adjacent buildings. These often constitute large areas of very high luminance.

Luminaires that are too bright for the environment will produce glare: discomfort glare or disability glare, or both. Discomfort glare produces visual discomfort without necessarily interfering with visual performance or visibility. Disability glare reduces both visibility and visual performance and is often accompanied by visual discomfort. To reduce direct glare, luminaires should be selected and positioned so that luminaires in the workers' normal line of sight are controlled within acceptable ratios. This precaution includes the use of supplementary lighting equipment.

Glare control depends on the task, the length of time to perform it, and those factors that contribute flexibility of functions and equipment and assure more uniform luminances. Alternate areas of extreme luminance differences are undesirable because it tires the eyes to adjust to them.

To reduce the luminance difference between the lighted surface of the luminaires and the adjacent ceiling areas, both the outer surfaces of the luminaires and the ceiling should have high reflectances. The luminaire should emit an appropriate upward component of light to brighten the ceiling. Light finishes throughout the space interior further contribute to illumination on the upper surfaces.

4.2.2 Discomfort glare

Discomfort glare is normally experienced as a feeling of discomfort which tends to increase with the passage of time and may contribute to fatigue.

The higher the luminance of the sources, the greater the solid angles they subtend, and the greater their number within the normal field, the greater the discomfort glare. The lower the luminance of the sources, the greater the angle formed by the direction of the source and the visual axis, and the higher the luminance of the background, the lesser the discomfort glare. Other parameters such as the characteristics of the eyes of the individual and the degree of visual concentration on the visual scene may also affect the degree of discomfort experienced.

Normally, the background luminance controls the general adaptation level of the eye. When the source becomes large, for example, in the case of a window, the effect of the source luminance on the adaptation level has to be taken into account.

4.2.3 Disability glare

Disability glare usually occurs when a large source of low luminance (or a small source of high luminance) is seen close to the line of sight to the visual task. An example is the difficulty in reading signs placed in front of, or close to, a window through which the sky is visible.

4.2.4 Reflected glare and veiling reflections

Reflected glare is glare from images of high luminance sources or from luminance differences reflected from any specular (shiny) surface. If the seeing task is on a shiny surface, reflected images of bright, overhead light sources may produce reflected glare. Less obvious are veiling reflections that obscure or reduce the visibility of task details. In certain instances, controlled reflections from properly located local light sources may be used to increase the visibility of details such as scribe marks on metal.

Reflected glare is frequently more annoying than direct glare because it is close to the line of vision and the eye cannot avoid it. In addition, veiling reflections may reduce task contrast; hence, it may become difficult to discern detail. There are several ways to minimise these occurrences:

a) the luminance of the source should be as low as possible, consistent with the type of work and surroundings. Luminaires with low-luminance light sources or with adequate shielding or diffusing media (or both) help to keep the luminance of reflected images within reasonable limits. Windows should have suitable shielding;

b) if the luminance of the light source or luminaire cannot be reduced, it may be possible to position either the lighting equipment or the task so that the reflected image will be directed away from the observer;

c) increasing the number of luminaires may diminish the effect of reflected glare and veiling reflections by increasing the illuminance on the task that is from luminaires located in positions other than those causing reflections; and

d) in special cases it may be practical to reduce the reflections from specular surfaces by changing the character of the offending surface.

4.2.5 Glare Index

Some tasks or interior environments require more critical attention to the control of discomfort glare. This applies particularly where one or more of the following conditions exist:

a) the room is large, resulting in a significant number of luminaires within the field of view of the occupants;

b) the visual tasks are difficult (e.g. small detail, poor contrast, rapid perception) and require sustained visual attention;

c) the direction of view of the works is at or above the horizontal for significant period, e.g. control rooms, some computer terminal work areas; and/or

d) the room surfaces and equipment are abnormally dark coloured or poorly lit.

For these situations, the degree of discomfort glare to the occupants of the interior may be predicted by the determination of a glare index using the formula-based method in CIBSE Publication TM10.

A higher value of glare index indicates a greater probability of discomfort glare and vice versa. The least perceptible difference of glare index is one unit, while the least difference which makes a significant change in the degree of discomfort glare is 3 units.

Table 1 gives the typical maximum glare index values for various industrial tasks and interiors.

Table 1 - Typical maximum glare index values for various industrial tasks or interiors:

Nature of Task or interior	Glare control required	Maximum glare index	Example of tasks or interior
Rough or intermittent tasks	Limited degree of glare control required	28	Raw material stores Concrete product manufacture Structural steel fabrication Welding and soldering (rough)
		25	Warehouses (packing and despatch) Boiler and turbine houses Machine and tool shops (rough bench and machine work) Plant rooms
Normal range of tasks or interiors	Glare control important	22	Corridors, passageways and stairs Food preparation and cooking Inspection and testing (coarse work) Assembly shops Sheet metal works Machine and tool shops (fine and medium machine work) Glass finishing (bevelling, etching, decorative cutting)
		19	Inspection and testing (medium work) Offices (general) Control rooms Machine and tool shops (gauge rooms)
Exacting visual tasks	High degree of glare control necessary	16	Printing industry (proof reading) Drawing offices (general and CAD/CAM) Fabric production (mending) Inspection and testing (fine work)

4.3 Colour quality of light source

With equal illumination, the various currently used white light sources probably have little or no effect upon the speed of seeing. However, these sources should be carefully selected where colour discrimination is important. Colour of light can affect a person's perception of space, colour and ambience of a room.

The colour qualities of a near-white lamp are characterized by two attributes:

a) its colour appearance; and

b) its colour rendering capabilities, which affect the colour appearance of objects illuminated by the lamp.

Both the colour appearance and the colour rendering properties of a light source are determined by the spectral composition of the light emitted. It is not possible to draw any conclusions regarding the colour rendering properties of a lamp from its colour appearance.

The colour appearance of a lamp refers to the apparent colour (chromaticity) of the light it emits. It may be described by its correlated colour temperature. Lamps normally used for interior lighting may be divided into 3 groups according to their correlated colour temperature (see Table 2). Information on the correlated colour temperature of particular lamps is normally given in the manufacturers' catalogues.

The colour rendering of a light source is the effect of that source on the colour appearance of object compared with their colour appearance under a reference illuminant. Colour rendering group 1 has the nearest effect as the colour rendering properties of the reference illuminant, while group 4 deviates the most (see Table 3).

Lamps should have colour rendering properties suited to their intended use. Good colour rendering may be required to achieve better discrimination between colours where that is part of the visual task. Alternatively, good colour rendering may be required to achieve a particular appearance or degree of comfort.

A warm apparent colour tends to be preferred for informal situations, at lower illuminances and in cold environments, whilst a cool apparent colour tends to be preferred for formal situations, at higher illuminances, and in hot environments. Adjacent areas should not be lit with sources of significantly different apparent colour unless a special effect is required.

Table 2 – Lamp colour appearance groups

Colour appearance group	Colour appearance	Correlated colour temperature K
1	Warm	below 3,300
2	Intermediate	3,300 to 5,300
3	Cold	above 5,300

NOTE:

Group 1: Preferred in social areas

Group 2: Is most widely used in working interiors

Group 3: Should be used only for high lighting levels, for specific tasks (like colour matching) or in warm climates.

Table 3 – Lamp colour rendering group

Colour rendering group	CIE colour rendering index (Ra)	Colour Appearance	Application	Example of use	
				Preferred	Acceptable
1A	Ra ≥ 90	Warm Intermediate Cold	Wherever accurate colour matching is required, e.g. colour printing inspection.	Colour matching	
1B	80 ≤ Ra < 90	Warm Intermediate	Wherever accurate colour judgements are necessary and/or good colour rendering is required for reasons of appearance, e.g. shops and other commercial premises	Offices	
		Intermediate Cold		Printing, paint and textile industries, demanding industrial work	
2	60 ≤ Ra < 80	Warm Intermediate Cold	Wherever moderate colour rendering is required	Industrial work	Office work
3	40 ≤ Ra < 60		Wherever colour rendering is of little significance but marked distortion of colour is unacceptable	Rough industries	Industrial work
4	20 ≤ Ra < 40		Wherever colour rendering is of no importance at all and marked distortion of colour is acceptable.		Rough industries

4.4 Distribution, reflection and shadow

Uniform horizontal illuminance (where the maximum level is not more than one-sixth above the average level; or the minimum, one-sixth below) is frequently appropriate for specific industrial interiors where tasks are closely spaced and there are similar tasks requiring the same amount of light. In such instances, uniformity permits flexibility of functions and equipment and assures more uniform luminances. If the luminance ratio is high, there may be a reaction of discomfort.

The illuminance on the vertical plane is important. Many tasks involving machining processes, control panels, assemblies, levers, gauges, shelving, and stacks are located in the vertical plane and require separate lighting design.

It is potentially a waste of energy to maintain uniformity between contiguous areas that have significantly different visibility and illumination requirements. (An example of such contiguous areas is a storage space adjacent to a machine shop). In such instances, it is prudent to design and apply illumination appropriate to each area. It may be accomplished by practicing one or a combination of the following two methods: using luminaires of different wattage or changing the quantity and spacing of luminaires in those areas. Local lighting restricted to a small work area is usually unsatisfactory unless there is sufficient general illumination.

Reflections of light sources in the task can frequently be useful if they do not create reflected glare or veiling reflections. In the machining and inspection of small metal parts, reflections can indicate faults in contour, make scribe marks more visible, and so on. Such reflections are usually created by carefully positioned local sources.

Shadows can accent the depth and form of objects, but harsh shadows should be avoided. Shadows may be softer and less pronounced when an object is illuminated from many sources or from large, diffusing luminaires; nevertheless, it is equally necessary to avoid confusing shadow patterns caused by nearby, multiple point sources. Clearly defined shadows without excessive luminance differences are distinct aids to some special functions such as engraving polished surfaces, some types of bench layout work, and certain textile inspections. When such shadow effect is needed, it is best obtained by supplementary, directional lighting combined with ample, diffused general illumination.

4.5 Luminance ratio

The ability to see task detail depends upon the luminance contrast of the detail against its background. Within limits, the greater the contrast, the easier the task is seen. Also, the eye functions most comfortably and more efficiently when the luminance within the surrounding environment are relatively uniform. Therefore, all luminance in the field of view should be carefully controlled.

It may not always be practical to achieve the desirable luminance relationships. Table 4 lists the varying degrees of practical environmental control and recommends luminance ratios for different interior areas. For normal viewing, luminance ratios in large industrial spaces should not exceed those given in Table 4. These ratios are recommended as maximum and their reductions are generally beneficial. If possible, it is better to have the task brighter than the surroundings. Whether the task is lighter or darker than its surroundings, the luminance ratios should not exceed those shown in lines (1) and (2) of Table 4. To achieve the recommended luminance ratios, it is necessary to select the reflectance of all room-surface and equipment finishes and to control the distribution and luminance characteristics of the luminaires relative to the pertinent space.

Surfaces with high reflectances are generally desirable to provide the recommended luminance ratios and high utilisation of light. They also improve the appearance of the workspace.

Table 4 – Recommended maximum luminance ratios

	Environmental classification		
	A	B	C
1) Between task and adjacent darker surrounding	3 to 1	3 to 1	5 to 1
2) Between task and adjacent lighter surrounding	1 to 3	1 to 3	1 to 5
3) Between task and more remote darker surface	10 to 1	20 to 1	*
4) Between task and more remote lighter surface	1 to 10	1 to 20	*
5) Between luminaries (or windows, skylights, etc.) and surfaces adjacent to them	20 to 1	*	*
6) Anywhere within normal field of view	40 to 1	*	*

* Luminance ratio control not practical.

A - Interior areas where reflectance of entire space can be controlled in line with recommendations for optimum seeing conditions.

B - Areas where reflectance of immediate work area can be controlled, but control of remote surrounding is limited.

C - Areas (indoor and outdoor) where it is completely impractical to control reflectance and difficult to alter environmental conditions.

4.6 Reflectance

The reflectance of the walls, ceiling, floor and equipment can determine the luminance pattern and influence seeing. Room and equipment finishes are significant in affecting utilisation of light, and hence, upon energy. The recommended reflectance values are presented in Table 5.

Table 5 – Recommended reflectance values applying to environmental classifications A and B of Table 4

Surfaces	Reflectance* (percent)
Ceiling	80 to 90
Walls	40 to 60
Desk and bench tops, machines and equipment	25 to 45
Floors	not less than 20

* Reflectance should be maintained as near as practical to the recommended values.

4.7 Colour of machines and surroundings

High reflectance, matt surfaces are generally beneficial because they provide a better luminance pattern, a higher utilisation of light, more economical use of energy and improved appearance of the room. Some companies may paint their machines in colours harmonious with the interior. It is preferable to have the background slightly darker than the seeing task. Painting stationary and moving parts of machines with contrasting colours may reduce hazards by aiding identification.

Colour can make the working environment more interesting and pleasant. Cream, ivory and buff are psychologically warm. Green, blue-green and blue are cool. Light grey finishes are neutral and excellent either for background or for equipment and machinery. The use of grey colour for both, however, can be sufficiently monotonous, resulting in a dull, unappealing environment. The use of stronger colours requires considerable care to assure a harmony that will wear well in an eight-hour

working environment. Strong colours should usually be limited to a relatively small portion of the visual field.

Colours for industrial spaces and machines should be chosen under the light sources that will be used in the space.

4.8 Flicker and stroboscopic effects

Fluctuations in light, either from a source or from an illuminated area in the field of view, are perceived if the frequency of fluctuations is low. This phenomenon of "flicker" can be troublesome and may give rise to effects such as annoyance. It varies greatly from individual to individual, as does the degree of discomfort experienced.

The frequency of flicker that can be perceived depends on the luminance and area of the source or illuminated field, the position at which its image falls on the retina, the shape of the luminance-versus-time curve and on the amplitude of the fluctuations. Fluctuations of light can also cause a "stroboscopic" effect, which can cause objects to appear to move jerkily or can mask the true speed of rotation.

The light output of all lamps on an a.c. supply has a cyclic variation which is small for most filament and fluorescent lamps and more marked for pure discharge lamps. The variation may cause flicker or stroboscopic effects, or both.

A fundamental cyclic variation of 100 Hz is present in the light emitted by lamps operating on the 50 Hz a.c. supply. This variation is very rapid and can rarely be detected visually. In some fluorescent lamps, however, a 50 Hz variation is also present, occurring mainly near the electrodes at the end of the lamp and seen by certain individuals as flicker. This can usually be avoided by appropriate shielding of the ends of fluorescent lamps. Flicker usually increases as fluorescent lamps age and can be avoided by regular replacement.

Flicker from high pressure mercury, metal halide and sodium discharge lamps is more noticeable in lamps with transparent envelopes than those with a fluorescent coating on the outer bulb.

Flicker due to a periodic fluctuation in supply voltage may also be evident but may not cause problems.

The stroboscopic effect produced on rotating machinery and other moving objects is annoying if the stroboscopic pattern appears on a task requiring special attention. It can be dangerous if it occurs on rotating parts of machinery because this might cause an impression of reduced speed, immobility or reversal of direction of rotation which might be potential risk factors. This can be avoided by lighting the revolving parts of the machines with individual incandescent lamps. Nevertheless the stroboscopic effect can be deliberately used for inspection purposes.

Stroboscopic effects may be reduced by dividing the lamps between three phases or, in the case of fluorescent lamps, by using lead-lag circuits. Flicker and stroboscopic effects may be most effectively reduced by operating the lamps from high frequency supplies.

4.9 Illumination level

Table 6 provides the general recommended maintenance illuminance for various types of tasks, activities or interiors. Maintenance illuminance is the value of the average illuminance below which it is necessary to take remedial action in terms of maintaining the lighting system, e.g. by replacing the lamps or by cleaning the luminaires, windows, rooflights and room surfaces.

Maintenance illuminance is different from "service illuminance" which is essentially an average value throughout the space and over the period between maintenance of the lighting system. It is also different from the "design value" recommended in SS CP 38.

Maintenance illuminance represents a minimum average illuminance which applies at all times through the life of the lighting system. This makes the task of assessing the system for compliance much easier. For design purposes, it will be necessary to select an initial illuminance which is significantly greater than the recommended maintenance illuminance to allow for progressive loss of light that will occur over time.

Illuminance levels for individual tasks should be increased where workers wear eye-protective devices with occupationally required tinted lenses that materially reduce the light reaching the eye.

Specific recommendations for different types of industrial tasks, activities and/or interiors are dealt with in Clause 8 of this code.

5 Lighting system

5.1 General lighting

The lighting characteristics of the visual environment affect both the physiological visual functions (visual performance) and the psychological visual functions (comfort) and may thus contribute to the performance, safety, visual comfort and satisfaction of occupants in their visual environment.

General lighting is intended to provide substantially uniform illumination throughout an area exclusive of any provision for special local requirements. Uniform illuminance is the distribution of light such that the maximum and minimum illuminance at any point is not more than one-sixth above or below the average level.

Production functions situated close to walls should have a general illuminance comparable to that in the central area. The distance between the wall and the adjacent luminaires should not exceed one-half the spacing between those in the central area. Closer spacing is often preferable.

5.2 Localised general lighting

In many factories, certain machinery or assembly and inspection tasks may require an illuminance higher than the general levels. It is good practice to increase the number of luminaires, the light output per luminaire, or both to provide the additional illuminance to these areas. If these work stations are in close proximity, a higher illuminance general lighting system may be more energy efficient than several localised general lighting systems.

5.2.1 Lighting requirements

The lighting of an interior should provide the optimum conditions for performing the tasks required and the appropriate visual environment when looking away from the task for relaxation or change of task. Special requirement may be needed in certain applications.

The visual impression of an interior is influenced by the appearance of the following surfaces:

a) main visual objects: for example, the tasks, and equipment;

b) large surface in the interior: walls, ceilings, floors, windows and surfaces of equipment; and

c) light sources: luminaires and windows.

Table 6 - General recommended maintenance illuminance for various types of tasks, activities or interiors

Class of task		Recommended maintenance illuminance lux	Characteristics of the activity/interior	Representative activity/interior
Movement and orientation		50	Interiors rarely visited. Visual tasks limited to movement and orientation	Corridors, Cable tunnels, Walk ways.
Rough intermittent		80	Interiors requiring intermittent use. Visual tasks limited to movement, orientation and coarse detail.	Staff change room, Live storage of bulky materials, Dead storage of materials needing care, Locker rooms, Loading bays.
Normal range of tasks and work places	Simple	160	Any continuously occupied interior where there are no tasks requiring perception of other than coarse detail. Occasional reading of clearly printed documents for short periods.	Waiting rooms, Staff canteens, Rough checking of stocks Rough bench and machine work Entrance halls General fabrication of structural steel Casting concrete Automated process monitoring.
	Ordinary or moderately easy	240	Continuously occupied interiors with moderately easy visual tasks with high contrasts or large details	Medium woodworking, Food preparation, Counters for transactions.
	Moderately difficult	320	Areas where visual tasks are moderately difficult with moderate details or with low contrasts.	Routine office work, Reading, writing, typing, Enquiry desks.
		400		Inspection of medium work, Fine woodwork.

Table 6 - cont'd

Class of task		Recommended maintenance illuminance lux	Characteristics of the activity/interior	Representative activity/interior
	Difficult	600	Areas where visual tasks are difficult with small detail or with low contrasts.	Drawing boards, Most inspection tasks, Proof reading, Fine machine work, Fine painting and finishing, Colour matching.
	Very difficult	800	Areas where visual tasks are very difficult with very small detail or with very low contrasts.	Fine inspection, Paint retouching, Fine manufacture, Grading of dark materials, Colour matching of dyes.
Extremely Difficult		1,200	Areas where visual tasks are extremely difficult with extremely small details or of low contrasts. Visual aids may assist.	Graphic arts inspection, Hand tailoring, Fine die sinking, Inspection of dark goods, Extra-fine bench work.
Exceptionally difficult		1,600	Areas where visual tasks are exceptionally difficult with extremely small details or with very low contrasts. Visual aids may assist.	Finished fabric inspection, Inspection of minute mechanisms, Jewellery and watchmaking.

NOTE – For older workers, a higher illumination level is recommended.

5.2.2 Lighting and design of task

In a work system, the visual field of an occupant is different depending on whether the occupant is concentrating on a task or looking away for relaxation. The criteria that shall be satisfied are different for both situations. For this reason a distinction is made between lighting of the task and lighting of the environment. The effectiveness of lighting the task is judged mainly by the criteria of visual performance. As the lighting of the environment can avoid causing distraction, unfavourable adaptation, and discomfort occurring in the field of view while performing the task, it can also play a part in assisting visual performance, which in turn improves the comfort and satisfaction experienced in carrying out the task.

In addition to contrasts of luminaire, the visual tasks usually include some colour contrasts. These can be used to improve conspicuity, especially when luminance contrasts are low.

5.2.3 Lighting of the environment

The relationships of the luminance and colours of the surfaces of the environment should be appropriate to the function of the interior, visually pleasing and free from glare.

Among the objectives sought, by providing appropriate lighting of the environment, are the following (not in order of priority):

a) to give the space adequate brightness in order to clearly define it;

b) to facilitate safe and easy movement in the interior;

c) to aid concentration on the task areas;

d) to provide areas of slightly lower luminance than the task areas;

e) to achieve natural modelling of faces and soften harsh shadows by the correct balance of directional and diffuse light;

f) to reveal the occupants and contents of the interior in acceptably 'natural' colours by the use of light sources of good colour rendering quality;

g) to produce, in a working interior, a pleasant variety of luminance and colour that contributes to the well-being of the occupants and to the reduction of work stress. One possible solution is to have small bright areas in the visual environment but not within the direct line of sight to the visual task; and

h) to encourage cleanliness by choosing light colours, particularly for floors and (in a workshop) machinery.

Certain elements may be found to be in conflict and appropriate compromises have to be found without sacrificing safety requirements and well-being.

5.2.4 Lighting of the task

Local lighting can be a very efficient method for providing adequate task illumination, particularly where high illuminances are necessary or flexible directional lighting is required. Local lighting is frequently provided by luminaires mounted on the workstation (e.g. desk lights).

Local lighting provides illumination only over the small area occupied by the task and its immediate surroundings. A general lighting system must be installed to provide sufficient ambient illumination for circulation and non-critical tasks. This is then supplemented by the local lighting system to achieve the necessary illuminance on tasks. The general surrounding illuminance should not be less than one-third of the task illuminance.

Considerable care should be taken to co-ordinate the lighting layout to task positions and orientation. The system can be inflexible and correct information is essential at the design stage. Changes in the work layout can seriously impair a localised system, although uplighters and other easily relocatable or switchable systems can overcome these problems.

Localised systems normally consume less energy than general lighting systems unless a high proportion of the area is occupied by workstations. This should be confirmed by specific calculations. Localised systems may require more maintenance than general lighting systems.

Local lighting must be positioned to minimise shadows, veiling reflections and glare. Although local luminaires allow efficient utilisation of emitted light, the luminaires themselves may be inefficient and can be expensive. Most local lighting systems are accessible and often adjustable. This increases wear and tear and hence maintenance costs but provides some individual control.

5.3 Practical considerations

5.3.1 Role of lighting in healthy work environments

The provision of a quality and healthy environment is essential in modern industrial processing facilities. Lighting can play an important part towards this. Artificial lighting can be planned with full regard to the provision made for natural lighting. In the case of multi-storey factories, where natural lighting comes predominantly from side windows, the artificial lighting should be capable of being used to supplement the natural lighting and should be separately switched in sections parallel to the window. The work environment should be stimulating and acceptable for the type of work involved. Distant views out to relax eyes and contact with the outside should be considered. Natural lighting helps provide safe environments and some useful illuminance due to the hour of day.

5.3.2 Illumination of exacting work areas

A regular overhead array of luminaires is usually installed to provide general lighting of an area. For situations where more exacting work is done within limited sections, the illuminance of such areas can be raised to an appropriate level by using sources of greater power or by reducing the luminaire spacing, or both. The choice of layout and lighting equipment will be affected by the available mounting height. Below 8 m, dispersive reflectors are normally used. For higher mounting, it may be more economical to use reflector systems giving a more concentrated light distribution. In either case, some upward light is desirable to prevent a tunnel effect.

5.3.3 Light sources

The choice will depend upon the location and the mounting height. Up to about 5 m, tubular fluorescent lamp is most commonly used for general lighting. The range of high-pressure discharge lamps with improved colour rendering should also be considered, particularly if the mounting height allows one of the higher wattage ratings to be used, thus reducing the number of luminaires required.

5.3.4 Light equipment (Luminaires)

Lighting equipment should comply with SS 263 appropriate to the conditions of use. Luminaires should be so designed as to facilitate installation or removal, maintenance and lamp changing.

The choice of equipment will be affected by the conditions under which it is operated. These conditions are either 'normal' where no special treatment of the lamp and equipment is necessary or 'hostile' requiring lamps and equipment to be protected against such conditions. Hostile environmental conditions include corrosive substances, extreme temperature and humidity.

5.3.5 Switching

Switching of luminaires should be flexible, to facilitate individual areas of work to be lit adequately and switched off or reduced in unwanted areas. Programmed lighting with microprocessor controls (including sensing of daylight penetration) should be used where appropriate.

5.3.6 Accessibility

Lamps and luminaires should be accessible without interference with tasks. For very high interiors, consideration should be given to the use of catwalks or similar means of obtaining access. The extra capital cost of this provision will often be justified by reduced maintenance charges, better lighting service and improved conditions of safety.

5.3.7 Critical colour requirements

In situations where critical colour matching is required, an illuminance of 1000 lux is recommended and the light sources should have a spectral quality in accordance with the requirements of BS 950. These sources have a lower luminous efficacy than those commonly used for general lighting, but it may only be necessary to provide this form of lighting over the inspection area and not in any adjacent general manufacturing areas.

5.4 Supplementary lighting

5.4.1 General

Difficult seeing tasks often require a specific quality or quantity of lighting that cannot readily be obtained from the general lighting system; one example is the additional lighting equipment over work benches adjacent to a wall. Such problems are frequently solved by using supplementary luminaires. Also, they may be used to furnish a specific luminance or colour, or to permit special aiming or positioning of light sources.

Before supplementary lighting can be specified, it is necessary to recognise the nature of the visual task and to understand its reflecting or transmitting characteristics. Improvement in the visibility of the task will depend upon one or more of the four fundamental visibility factors: luminance, contrast, size and time.

Planning supplementary lighting involves the consideration of visual comfort or workers in peripheral areas. Supplementary equipment should protect the user and neighbour from glare.

Luminance ratios should be carefully controlled: workers frequently relax by glancing away from a task. They should not be forced to encounter luminance that are extremely different from those of the task. To reduce this possibility, it may be advisable to use window coverings to reduce outdoor luminance; or to install luminaires in a position to increase the luminance of an otherwise dark wall. It may be necessary to coordinate the design of supplementary, general, and localised general lighting.

5.4.2 Lighting of difficult seeing tasks

Table 7 is a guide to applying the appropriate luminaire types to various tasks. An industrial situation may involve more than one seeing task and may require combined lighting techniques.

Table 7 – Classification of visual tasks and lighting techniques used in supplementary lighting

FLAT SURFACES				
Classification of visual task	Example		Lighting technique	
General characteristics	Description	Lighting requirements	Luminaire type	Locate luminaire
A. Opaque materials				
1. Diffuse detail and background				
a. Unrboken surface	Newspaper proof reading	High visibility with comfort	S-III or S-II	To prevent direct glare and shadows
b. Broken surface	Scratch on inglazed tile	To emphasize surface break	S-I	To direct light obliquely to surface
2. Specular detail and background				
a. Unbroken surface	Dent, wraps, uneven surface	Emphasize unevenness	S-V	So that image of source and pattern is reflected to eye
b. Broken surface	Scratch, scribe, engraving, punch marks	Create contrast of cut against specular surface	S-III or	So detail appears bright against a dark background
			S-IV or S-V when not practical to orient task	So that image of source is reflected to eye and break appears dark
c. Specular coating over specular background	Inspection of finish plating over underplating	To show up uncovered spots	S-IV with colour of source selected to create maximum colour contrast between two coatings	For reflection of source image toward the eye
3. Combined specular and diffuse surfaces				
a. Specular detail on diffuse light background	Shiny ink or pencil marks on dull paper	To produce maximum contrast without veiling reflections	S-III or S-IV	So direction of reflected light does not coincide with angle of view
b. Specular detail on diffuse dark background	Punch or scribe marks on dull metal	To create bright reflection from detail	S-II or S-III	So direction of reflected light from detail coincides with view

Table 7 – cont'd

FLAT SURFACES				
Classification of visual task	Example		Lighting technique	
General characteristics	Description	Lighting requirements	Luminaire type	Locate luminaire
c. Diffuse detail on specular, light background	Grduation on a steel scale	To create a uniform, low-brightness reflection from specular background	S-IV or S-III	So reflected image of source coincides with angle of view
d. Diffuse detail on specular, dark background	Wax marks on automotive body	To produce high brightness of detail against dark background	S-III or S-II	So direction of reflected light does not coincide with angle of view
B. Translucent materials				
a. With diffuse surface	Frosted or etched glass or plastic, lightweight fabrics hosiery	Maximum visibility or surfaces detail Maximum visibility of detail within material	Treat as opaque, diffuse surface Transilluminate behind material with S-II, S-III, or S-IV	
b. With specular surface	Scratch on opal glass or plastic	Maximum visibility of surfaces detail Maximum visibility of detail within material	Treat as opaque specular surface Transilluminate behind material with S-II, S-III, or S-IV	
C. Transparent materials				
Clear material with specular surface	Plate glass	To produce visibility or details within material such as bubbles and details on surface such as scratches	S-V and S-I	Transparent material should move in front of Type S-V, then in front of black background with Type S-I directed to prevent reflected glare

Table 7 – cont'd

Classification of visual task	Example		Lighting technique	
General characteristics	Description	Lighting requirements	Luminaire type	Locate luminaire
FLAT SURFACES				
D. Transparent over opaque materials				
a. Transparent material over diffuse background	Instrument panel	Maximum visibility of scale and pointer without veiling reflections	S-I	So reflection of source does not coincide with angle of view
	Varnished desk top	Maximum visibility of detail on or in transparent coating or on diffuse background Emphasis of uneven surface	S-V	So that image of source and pattern is reflected to the eye
b. Transparent material over a specular background	Glass mirror	Maximum visibility of detail on or in transparent material	S-I	So reflection of source does not coincide with angle of view. Mirror should reflect a black background.
		Maximum visibility of detail on specular background	S-V	So that image of source and pattern is reflected to the eye.
THREE DIMENSIONAL OBJECTS				
A. Opaque materials				
1. Diffuse detail and background				
Diffuse detail and background	Dirt on a casting or blow holes in a casting	To emphasize detail with a poor contrast	S-III or S-II or S-I or S-III or S-II as a "black light" source when object has a fluorescent coating	To prevent direct glare and shadows In relation to task to emphasize detail by means of highlight and shadow To direct ultraviolet radiation to all points to be checked

Table 7 – cont'd

THREE DIMENSIONAL OBJECTS				
Classification of visual task	Example		Lighting technique	
General characteristics	Description	Lighting requirements	Luminaire type	Locate luminaire
2. Specular detail and background				
a. Detail on the surface	Dent on silverware	To emphasize surface unevenness	S-V	To reflect image of source to eye
	Inspection of finish plating over underplating	To show up areas not properly plated	S-IV plus proper colour	To reflect image of source to eye
b. Detail in the surface	Scratch on a watch case	To emphasize surface break	S-IV	To reflect image of source to eye
3. Combination specular and diffuse				
a. Specular detail on diffuse background	Scribe mark on casting	To make line glitter against dull background	S-III or S-II	In relation to task for best visibility. Adjustable equipment often helpful Overhead to reflect image of source to eye
b. Diffuse detail on specular background	Micrometer scale	To create luminous background against which scale markings can be seen in high contrast	S-IV or S-III	With axis normal to axis of micrometer

Table 7 – cont'd

THREE DIMENSIONAL OBJECTS				
Classification of visual task	Example		Lighting technique	
General characteristics	Description	Lighting requirements	Luminaire type	Locate luminaire
B. Translucent materials				
a. Diffuse surface	Lamp shade	To show imperfections in material	S-II	Behind or within for transillumination
b. Specular surface	Glasss enclosing globe	To emphasize surface irregularities	S-V	Overhead to reflect image of source to eye
		To check homogeneity	S-II	Behind or within for transillumination
C. Transparent materials				
Clear material with specular suface	Bottles, glassware – empty or filled with clear liquid	To emphasize surface irregularities	S-I	To be directed obliquely to objects
		To emphasize cracks, chips and foreign particles	S-IV or S-V	Behind for transillumination. Motion of objects is helpful.

5.4.2.1 Classification of visual tasks and lighting techniques

Visual tasks, unlimited in number, may be classified according to certain common characteristics. Applying certain lighting fundamentals can determine the detail to be seen in each group. Table 7 classifies tasks according to their physical and light-controlled characteristics and suggests lighting techniques for good visual perception.

When using Table 7, note that the classification of visual tasks is based upon the prime and fundamental visual task characteristics – not upon the general applications. For example, on a drill press, the visual task might be the discernment of a punch mark on metal. This could be a specular detail with a diffuse, dark background (classification A.3b. in Table 7). Luminaire types S-II or S-III are recommended.

5.4.2.2 Luminaires for supplementary lighting

Supplementary lighting luminaires may be divided into five major types according to candlepower distribution and luminance, as follows (see Table 7):

Type S-I – directional: includes all concentrating units. Examples of this type are reflector spot lamps or luminaires with concentrating reflectors or lenses. Other examples in the group are concentrating, longitudinal units such as a well-shielded fluorescent lamp in a concentrating reflector.

Type S-II – spread, high-luminance: includes small-area sources [incandescent or High Intensity Discharge (HID)]. An example of this type is an open-bottom, deep-bowl diffusing reflector with a high-pressure sodium lamp.

Type S-III – spread, moderate-luminance: includes all fluorescent units having a variation in luminance greater than two-to-one.

Type S-IV – uniform-luminance: includes all units having less than a two-to-one variation of luminance. Usually, this luminance is less than 6800 cd/m^2. An example of this type is an arrangement of lamps behind a diffusing panel.

Type S-V – uniform-luminance with pattern: is a luminaire similar to Type S-IV except that a pattern of stripes or lines is superimposed on the panel.

5.4.2.3 Portable luminaire

Wherever possible, supplementary luminaires should be permanently located to produce the lighting effect most appropriate for the intended function. Adjustable arms or swivels (or both) will often adapt the luminaires to the required flexibility. Portable equipment may be feasible around movable machines or objects such as in aircraft assembly areas or garages or for seeing internal surfaces. The luminaires must be mechanically and electrically rugged and the lamps should be guarded and of a type to withstand possible rough service. Guards or other means should protect the user from excessive heat. Precautions should be taken to prevent electric shock.

5.5 Emergency evacuation lighting

During a failure of the normal power supply, protruding machines or objects are often seen in silhouette. Generally, emergency lighting is designed to provide lighting for two basic conditions:

a) short duration, for personnel safety and evacuation; and

b) longer durations where lighting is required for security or for continuity of critical conditions. Each of these conditions warrants the use of a stand-by power supply.

Temporary power interruptions and severe line voltage dips may require special consideration. In locations where the lighting is provided by HID sources, emergency lighting may be needed for temporary lighting during the HID lamp restrike period. Some HID luminaires can be equipped with an incandescent source that will light immediately upon return to normal power, and will remain lighted until 70 to 90 percent of the HID output returns.

Luminaires can be equipped with battery-powered units that provide reduced illuminance for time intervals adequate for safety of workers. For longer outages, it may be better to rely upon power supplied by storage batteries or emergency generators. Either or both may be used to meet the necessary requirements. An emergency lighting system may be part of, or separate from, the regular lighting system. Planned, periodic maintenance of all components of the emergency system is essential to its proper function. Installations must comply with applicable codes and regulations.

Storage-battery lighting units automatically provide lighting in corridors, stairwells, exits, aisles (any exit routes for the safe passage and egress of personnel), equipment rooms and other critical areas. Battery capacity and the number of lamps and their wattages should be so correlated to provide lighting for at least the length of time required by applicable codes.

Generator sets are power sources for longer durations of emergency lighting. The generators are driven by a prime mover that automatically starts upon failure of the normal power supply. Transfer from normal to emergency power may be effected by an automatic transfer switch.

5.6 Safety lighting

Safety lighting should be installed, when required, at those workstations where the absence of the normal lighting will place the worker in a hazardous situation. Examples of such circumstances include the following:

a) where the worker is engaged in potentially hazardous work, such as handling or control of hot metal; and

b) where safety demands that machines or processes be terminated in a controlled manner.

The work area requiring safety lighting should be provided with an illuminance of at least 10% of the maintenance illuminance recommended for the same area under the normal lighting. However, the illuminance should in any event be not less than 20 lux. The appropriate illuminance should be provided within 0.5 s of failure of the normal supply.

Safe working conditions are essential to any industry and the effect of light on safety must be considered. The environment of an industrial installation should be designed to help compensate for the limitations of human capability. Any factors that aid visual effectiveness increase the probability that a worker will detect the potential cause of an accident and act to correct it.

The colour rendering properties of the light source should be considered with regard to the physical hazards present in the particular installation. Special consideration should be given in regard to discrimination of safety colours under high pressure sodium lighting.

In many instances where illumination is associated with industrial accidents, the cause is attributed to inadequate illuminance or poor quality of illumination. However, there are many less tangible factors associated with poor lighting that can contribute to industrial accidents. Some of these factors are: direct glare, reflected glare from the task, and harsh shadows – all of which affect seeing. Excessive visual fatigue itself may be an element leading to accidents.

Accidents may also be due to the delayed eye adaptation a person experiences when moving from bright surroundings into dark ones and vice versa. Some accidents that have been attributed to an individual's carelessness could have been partially due to difficulty in seeing from one or more of the above mentioned factors. The accidents might have been avoided through good lighting.

A visually safe installation must minimise glare and be free of uncontrolled large differences in illuminances. Changes in eye adaptation when alternately looking at areas of widely different luminances will occur, and the recommended maximum luminance ratios listed in Table 4 should be used to avoid temporarily noticeable reductions in visibility. Connecting adjacent fluorescent and HID luminaires to different phases of three-phase electrical distribution systems will reduce stroboscopic effects and, therefore, improve safety in machine shops and other areas with rotating machinery.

5.7 Security lighting

Security lighting pertains to the lighting of building exteriors and surrounding areas out to and including the boundaries of the property. In some cases, it may be an integral part of the industrial lighting design.

Security lighting contributes to a sense of personal security and protects property and may be realised by:

a) surveillance lighting – lighting to detect and observe intruders;

b) protective lighting – lighting to discourage or deter attempts at entrance or vandalism; and

c) lighting for safety – lighting to permit safe movement of guards and other authorised persons.

An effective security lighting system should:

a) discourage intruders;

b) make detection highly probable should entry occur;

c) avoid glare that handicaps guards, as well as annoys legitimate occupants of adjacent properties, passing traffic, and passers-by;

d) provide adequate illuminance. Illuminance needed depends upon the accessibility and vulnerability of the property and whether the surveillance is by eye or by electronics;

e) provide low illuminance on guard posts, surveillance cameras and other electronic or sensing devices to render their positions harder for the intruder to notice;

f) provide complete reliability. A single lamp outage should not result in a dark spot vulnerable to entry; and

g) provide convenient control and maintenance.

5.8 Standby lighting

Standby lighting enables normal activities to continue, should the supply to the normal lighting fail. The quantity and quality of the standby lighting should therefore satisfy the recommendations of this code for the various activities concerned.

Standby lighting is generally provided by the energisation of some or all of the normal luminaires from an alternative power supply.

5.9 Supplementary lighting for maintenance tasks

For some applications, the illuminances needed for maintenance task will be higher than those for the normal use of the space. In such circumstances, the illuminance required for maintenance tasks may be provided by either:

a) a permanently installed supplementary system of lighting, capable of being switched on when maintenance is to be carried out; or

b) portable luminaires which are put in place when maintenance is required.

The choice of which alternative is used will depend on the type of maintenance tasks to be performed and the anticipated frequency of maintenance. Advice should be sought on which type of maintenance lighting is appropriate for the application, and on the associated requirements.

6 Lighting measurement

6.1 Measurement of illumination level

This section describes how illumination levels should be measured at visual task, workroom or work area. The results of measurement can be used to verify the design illumination levels of a new lighting system or determine compliance with the recommended maintenance illumination levels in Clause 8 of this code.

Illumination level measurements should be made by means of a photometer or light meter calibrated with a standard light source.

The photocell or sensor should be cosine-corrected with a layer of opal material or cupola of opal glass as an integral part of the sensor to take account of the effects of light falling on it at oblique angles.

It should also be colour corrected with a suitable filter to account for the response of the eye to light of different colours. If the photocell is not colour corrected, the appropriate colour correction factor (as supplied by the manufacturer) should be applied.

The scale range should be such that readings can be taken at not less than 1/5 of the full scale value of the range.

6.1.1 Conditions of measurement

The illumination level measurement in building interiors should be made in the absence of natural or daylight. If much light is contributed by daylight, the measurement should be repeated at night to determine the adequacy of artificial light.

All newly installed lighting or replaced luminaires should be aged by operation for at least 20 h for incandescent lamps and 100 h for fluorescent and discharge lamps before measurements are made.

Prior to the measurement, all lamps should be operated for sufficient time to allow the light output of the lamps to stabilize, usually 1 h for discharge lamps.

The photocell should be exposed to light for about 5 min or until the reading becomes stabilised before the first reading is taken.

The surveyor should wear dark coloured clothes to eliminate reflectance interference. Care should be taken not to cast a shadow on the photocell when taking a reading.

6.2 Locations of measurements

6.2.1 Visual task area

The illumination level should be measured at the location where the task is being carried out. Care should be taken not to interfere with the way the work is being carried out or the light falling on to the task.

The photocell should be placed in the appropriate plane (horizontal, vertical or inclined) of the work. This should be made with the person in his or her normal work position, even if this results in a shadow on the photocell.

Where the area of the visual task is small, at least one measurement should be taken in the centre of this area.

Where the task area is large, a number of measurements should be made within the task area and the average illumination level calculated from all the readings.

6.2.2 General area

The area of a workroom should be divided into 1 m squares and the illumination levels should be measured in the centre of each square, and at a height of 70 cm (for desk work) or 85 cm (for bench work) above the floor.

In industrial high-bays with a larger spacing of luminaires, the distance between measuring points may be 5 m and above.

In circulation areas, the height of the measuring plane should not be more than 20 cm.

The average illumination level for the whole area is obtained by taking the arithmetic average of the individual measurements.

6.3 Measurement of luminance

Luminance measurements should be made under actual working conditions from relevant work locations. The luminance meter is held at the level of the subject's eyes and directed towards the surface concerned.

To check for compliance with 4.5 of this code, the luminance of the following surfaces should be measured: visual task, immediate surroundings of the task, general background of the task including walls and ceiling.

6.4 Illumination check list

The following checklist helps to evaluate whether a visual environment is satisfactory, and to identify whether there is a need for maintenance, modification or replacement of lamps and fixtures:

a) What is the overall appearance of the area from the standpoint of visual comfort?

b) Is there enough general lighting? What about supplementary lighting?

c) How dirty are the lamps and fixtures? When were they last cleaned?

d) How many lamps are burned out or not functioning properly?

e) What colours are the walls, ceiling and equipment? Are the colours acceptable from the standpoint of reflectance values?

f) Are there any obvious sources of direct glare or reflected glare?

g) Are workers subjected to bothersome shadows?

h) What changes could be made to improve the visual environment?

7 Maintenance of lighting installation

Proper maintenance procedures and schedule for lighting installation are necessary to ensure optimum life span and efficiency. Maintenance should be carefully planned in order for it to be carried out safely and conveniently without disrupting existing work operation or processes. This would minimise the need for down time and maintain existing work productivity without having to increase unnecessary cost.

Maintenance of lighting installation when properly carried out reduces deterioration of equipment, promotes safety, ensures lighting performance within design limits, and helps to reduce electrical load and costs.

Maintenance includes replacement of failed or faulty lamps, control gear and cleaning of luminaries and room surfaces at suitable intervals.

7.1 Depreciation in illuminance

One method of establishing a suitable maintenance schedule is to periodically check the illuminance with a light meter. For a new installation, first readings should be taken after 100 hours of use and repeated at appropriate intervals. As for existing installation, the luminaire should be cleaned and new lamps installed, thereafter, the same measuring procedure for new installation should be followed. Maintenance would be required when readings have decreased to the established maintenance level (refer to Table 8).

7.1.1 Luminaires dirt depreciation

A significant amount of light loss is usually experienced due to dirt deposition on luminaire surfaces. The rate of dirt accumulation is dependent on the design of the luminaire, the location of the installation, the nature of the external environment and the type of activity. Depreciation of the luminaire varies with the amount of dirt accumulation.

7.1.2 Lamp lumen depreciation

The light output from a lamp decreases progressively with the duration of operation. Different lamp types deteriorate at different rates. The useful and optimum life span of a lamp is the period during which the lumen output does not fall below 75% of the rated initial value. Replacement of lamp should be carried out once this life is reached.

7.1.3 Room surface dirt depreciation

The illuminance of a workplace is a mixture of light from the luminaire and diffused light reflected back from the ceiling and walls. Dirt and dust deposited on room surfaces depreciate the transmission and reflection factor affecting the illuminance within a room.

7.2 Cleaning

The type of contaminant, the efficiency of air filtering systems, the amount of traffic, and other variables determine the frequency of cleaning. Regular cleaning helps to restore certain degree of the illuminance.

7.2.1 Cleaning of luminaires

The appropriate cleaning interval for luminaires and the lamps they contain is an economic decision. The factors that need to be considered are the cost and convenience of cleaning at a particular time. As a general practice, luminaires should be cleaned at least once a year. However, for some locations this may not be sufficient and cleaning should be carried out more often.

For maximum economic advantage, the luminaire cleaning should be related to lamp replacement interval.

7.2.2 Cleaning of room surface

Room surfaces in factories should be cleaned and repainted regularly. Regular cleaning is particularly important where light reflected from the room surfaces makes an important contribution to the lighting of the interior.

Clean room surfaces increase lighting utilisation. The use of light coloured wall and white ceilings is recommended.

7.2.3 Group relamping

Lamps are normally replaced individually with new ones when they failed, as it is important to maintain the average lighting level. However, in large buildings, if the entire installation can be relamped at one time, cost can be reduced by organising group replacement instead of replacing lamps individually. With group relamping, a higher maintenance factor could be applied.

8 Lighting recommendations

8.1 Specific type of interiors or activities

Table 8 provides the quantitative and qualitative lighting recommendations for the interiors and activities commonly encountered in a range of industries. It should be noted that the information given in the table is applicable for general situations.

A higher illuminance may be used under the following circumstances:

a) when unusually low reflectance or contrast is present in the activity;

b) when visual performance is critical;

c) when accuracy or higher productivity is of great importance; and

d) when the visual capacity of the worker makes it necessary.

A lower illuminance may be used under the following circumstances:

a) when reflectance or contrast is unusually high;

b) when speed or accuracy is not importance; and

c) when the activity is executed only occasionally.

The appearance of many working areas is dim at illuminance less than about 200 lux.

The minimum illuminance recommended for long periods of work at a fixed work space is 200 lux, irrespective of the visual ease of the activity.

Lighting system may need to combine general and local lighting to achieve high illuminances for certain activities.

8.2 Recommendations for visual display activities

Table 9 provides the lighting recommendations for activities or work areas involving visual displays, control and monitoring panels or rooms, and other screen-based activities.

The following points should be noted:

a) local lighting of the control display and the control desk may be appropriate;

b) care should be taken to avoid shadows and veiling reflections occurring on instruments;

c) care should also be taken to avoid reflections on screens of visual display terminals;

d) where a mainly self-luminous display is used, the ability to dim the room light may be useful; and

e) where a large mimic diagram containing details which has to be seen from a considerable distance is used, special lighting providing a minimum illuminance of 500 lux on the diagram is desirable.

Table 8 – Lighting recommendations

	Type of interior or activities	Maintenance Illuminance lx (Note 1)	Lamp colour appearance group (Note 2)	Lamp colour rendering group (Note 3)	Maximum glare index (Note 4)	Other recommendations
1.	*AIRCRAFT MAINTENANCE*					
	Maintenance hangers	400	1 or 2	2	22	Additional local lighting may be necessary for some tasks.
2.	*ASSEMBLY SHOPS, MANUFACTURING PROCESSES, MACHINE SHOPS, FITTING SHOPS, INSPECTION (Note 5)*					
	Rough work, rough visual inspection	160 or 240	1 or 2	2 or 3	25	1) Higher illuminance value applicable where elements of task detail are small or low in contrast. 2) See Note 6.
	Medium work, ordinary automatic machines, rough grinding, medium buffing and polishing, inspection of electronic equipment sub-assemblies	400	1	2	19	-
	Fine work, fine automatic machines, medium grinding, fine buffing and polishing, inspection of calibrated scales, inspection of precision mechanisms and instruments	600	1, 2 or 3	1B or 2	19	The use of local lighting is desirable.
	Extra-fine work, fine grinding, tool and die making, gauging and inspection of small or intricate parts of sub-assemblies or mechanisms	1,200	3	1A	n.a.	1) The use of local lighting is essential. 2) Optical aids are recommended.
	Minute work, very small instruments	1,600	3	1A	n.a.	1) The use of local lighting is essential. 2) Optical aids are recommended.
3.	*BAKERIES AND CONFECTIONERY MANUFACTURE*					
	General working areas	160	1 or 2	2 or 3	22	-
	Mixing and make-up rooms, cream making	240	1 or 2	2	22	-
	Decorating, icing, inspection, wrapping, packing	400	1 or 2	1A or 1B	22	See also PACKING AND DISPATCH

	Type of interior or activities	Maintenance Illuminance lx (Note 1)	Lamp colour appearance group (Note 2)	Lamp colour rendering group (Note 3)	Maximum glare index (Note 4)	Other recommendations
4.	*BREWING, DISTILLING AND SOFT-DRINK MANUFACTURE*					
	General working area	160	1 or 2	2 or 3	25	See Note 6.
	Brewhouse, bottling and canning plants	240	1 or 2	2 or 3	25	See Note 6.
	Bottle inspection	*	*	*	*	* Special requirements apply - provision of contrasting backgrounds.
5.	*BUILDING CONSTRUCTION SITE (INTERIOR)*					
	Walkway and access areas	50	1 or 2	2 or 3	n.a.	Higher illuminances on relevant surfaces may be required depending on the degree of hazard.
	General work areas	160	1 or 2	2 or 3	n.a.	1) Illuminance should be provided on the plane of the task over the whole working area. 2) Illuminance may be reduced if the task requires little perception of detail or is carried out for a short period. 3) Additional local lighting or higher levels of general lighting may be needed for more difficult visual tasks.
6	*CLAY PRODUCTS*					
	Grinding, moulding, trimming, firing	240	1 or 2	2 or 3	28	See Note 6.
	Enamelling, colouring, glazing	600	1 or 2	1A or 1B	19	The use of local lighting is desirable.
7.	*CLOTHING MANUFACTURE*					
	Fabric inspection and testing	1,200	3	1A or 1B	n.a.	The use of local lighting is essential.
	Pattern making	400	1 or 2	1B or 2	22	-
	Layout and cutting	600	1, 2, or 3	1B or 2	19	-

	Type of interior or activities	Maintenance Illuminance lx (Note 1)	Lamp colour appearance group (Note 2)	Lamp colour rendering group (Note 3)	Maximum glare index (Note 4)	Other recommendations
	Sewing	800	2 or 3	1B or 2	19	The use of local lighting is recommended.
	Pressing	400	1 or 2	1B or 2	22	-
	Hand tailoring and repairs	1,200	3	1A or 1B	n.a.	The use of local lighting is essential.
	Inspection of finished goods	1,200	3	1A or 1B	n.a.	The use of local lighting is essential.
8.	*CONCRETE PRODUCTS*					
	Mixing, casting, cleaning, drying, curing	160	1 or 2	3 or 4	28	See Note 6.
9.	*DAIRY FACTORIES*					
	Filling milk	250	1 or 2	2 or 3	25	See Note 6
10.	*EDIBLE OILS AND FATS PROCESSING (Note 7)*					
	Refining and blending	240	1 or 2	2 or 3	25	See Note 6.
	General work areas	400	1 or 2	2 or 3	22	-
11.	*ELECTRICAL EQUIPMENT MANUFACTURE*					
	General work area	240	1 or 2	2 or 3	25	See Note 6.
	Medium assembly work	400	1 or 2	2	22	-
	Fine assembly work	800	1, 2 or 3	1B or 2	19	The use of local lighting is desirable.
	Extra-fine assembly work	1,200	3	1A	n.a.	1) The use of local lighting is essential. 2) Care is necessary to control specular reflection. 3) Optical aids may be useful.
12.	*ELECTRICITY GENERATING STATIONS*					
	General plant areas	160	1 or 2	2	25	See Note 6.

	Type of interior or activities	Maintenance Illuminance lx (Note 1)	Lamp colour appearance group (Note 2)	Lamp colour rendering group (Note 3)	Maximum glare index (Note 4)	Other recommendations
	Maintenance work	400	1, 2 or 3	2	25	1) Supplementary local lighting may be necessary for special maintenance tasks. 2) See Note 6.
	Instruments, gauges, valves, and similar	160	1 or 2	2 or 3	n.a.	See section 8.2 and Table 9 of this code.
13.	*ELECTRONIC EQUIPMENT MANUFACTURE AND REPAIR*					
	Printed circuit board preparation	400	1 or 2	2	22	-
	Hand insertion of components, soldering	600	1, 2 or 3	1B or 2	19	The use of local light is desirable.
	Inspection and testing	800	2 or 3	1A or 1B	n.a.	1) The use of local light is recommended. 2) Magnification may be desirable for inspection. 3) A large, low luminance luminaire located overhead may be helpful in providing suitable visual conditions for inspection of printed circuits.
	Silk screening	400	1 or 2	2	22	The use of local lighting is desirable.
14.	*FLOUR MILLING*					
	Cleaning, grinding or rolling	160	1 or 2	2 or 3	25	1) Additional local lighting may be necessary 2) See Note 6.
	Baking and roasting	240	1 or 2	2	22	-
	Flour grading	400	1 or 2	1B	22	-
15.	*FOOD PROCESSING (INCLUDING CANNING, PRESERVING AND FREEZING)* *(Note 8)*					
	Grading and sorting of raw materials	600	1 or 2	2 or 3	22	The use of local lighting is desirable.
	Preparation, cleaning, dicing, trimming	240	1 or 2	2	25	See Note 6.

	Type of interior or activities	Maintenance Illuminance lx (Note 1)	Lamp colour appearance group (Note 2)	Lamp colour rendering group (Note 3)	Maximum glare index (Note 4)	Other recommendations
	Labelling and packaging	-	-	-	-	See PACKING AND DISPATCH
	Frozen foods process areas	240	1 or 2	2	25	See Note 6.
16.	*FOUNDRIES (Note 9)*					
	Charging, sand preparation, tumbling, cleaning, pouring, shell moulding, shaking out	160	1 or 2	2 or 3	28	See Note 6.
	Fettling, sand and shot blasting	240	1 or 2	2 or 3	25	See Note 6.
	Rough moulding and core making	160	1 or 2	2 or 3	28	See Note 6.
	Fine moulding and core making, inspection	400	1 or 2	2 or 3	22	-
	Patterning making	-	-	-	-	See WOODWORKING, SAWMILLS AND TIMBER PROCESSING PLANT
17.	*FURNITURE FACTORIES*					
	Wood machining and assembly:					
	(1) Rough sawing and cutting	240	1 or 2	2 or 3	22	-
	(2) Machining, sanding and assembly of components	400	1 or 2	2	22	-
	Cabinet making:					
	(a) Veneer sorting and preparation	600	1, 2 or 3	1B or 2	19	The use of local lighting is desirable.
	(b) Veneer pressing	400	1 or 2	2 or 3	22	-
	(c) Fitting	400	1 or 2	2 or 3	22	-
	(d) Final inspection	600	1, 2 or 3	1B or 2	22	The use of local lighting is desirable.
	(e) Tube bending and cutting	240	1 or 2	2	22	-

	Type of interior or activities	Maintenance illuminance lx (Note 1)	Lamp colour appearance group (Note 2)	Lamp colour rendering group (Note 3)	Maximum glare index (Note 4)	Other recommendations
	Upholstery:					
	(a) Material inspection	800	2 or 3	1B or 2	n.a.	The use of local lighting is recommended.
	(b) Filling and covering	400	1 or 2	2	22	-
	(c) Slipping	600	1, 2 or 3	1B or 2	22	The use of local lighting is desirable.
	(d) Cutting, sewing	600	1, 2 or 3	1B or 2	22	The use of local lighting is desirable.
	Mattress making:					
	(a) Assembly	400	1, 2 or 3	1B or 2	22	-
	(b) Tape edging	800	2 or 3	1B or 2	22	The use of local lighting is recommended.
18.	*GLASS MANUFACTURING AND PROCESSING*					
	Mix and furnace rooms, pressing, glassblowing machines, polishing	160	1 or 2	2	28	See Note 6.
	Grinding, cutting glass to size, silvering	240	1 or 2	2	28	See Note 6.
	Fine grinding, bevelling, inspection, etching and decorating	400	1 or 2	2	22	-
	Glass cutting (cut glass)	600	1, 2 or 3	1B or 2	22	The use of local lighting is desirable.
	Fine inspection	-	-	-	-	Special requirements apply.
19.	*HOSIERY AND KNITWEAR MANUFACTURE*					
	Flat-bed knitting machines	400	1 or 2	2	22	-
	Circular knitting machines	600	1, 2 or 3	1B or 2	19	The use of local lighting is desirable.
	Lockstitch and over-locking machines	800	2 or 3	1B or 2	19	The use of local lighting is recommended.
	Linking or running-on	800	2 or 3	1B or 2	19	The use of local lighting is recommended.

	Type of interior or activities	Maintenance illuminance lx (Note 1)	Lamp colour appearance group (Note 2)	Lamp colour rendering group (Note 3)	Maximum glare index (Note 4)	Other recommendations
	Mending, hand finishing, inspection	1,200	3	1A or 1B	n.a.	The use of local lighting is essential.
20.	*IRON AND STEEL MAKING*					
	Sinter plant, mixing drum, fan house, screen houses, coolers, transfer stations, furnaces	160	1 or 2	3 or 4	28	See Note 6.
	Electric melting shops, general oxygen steel making plants	160	1 or 2	2	28	See Note 6.
	Control platforms and pulpits	-	-	-	-	See section 8.2 and Table 9 of this code.
	Scrap bays	160	1 or 2	4	28	See Note 6.
21.	*JEWELLERY MANUFACTURING*					
	General lighting for working areas	400	1 or 2	1B or 2	19	-
	Fine processes	600	1, 2 or 3	1A or 1B	19	The use of local lighting is desirable.
	Minute processes	1,600	3	1A	n.a.	(1) The use of local lighting is essential. (2) Optical aids are recommended.
	Gem cutting, polishing, setting	1,200	3	1A or 1B	n.a.	(1) The use of local lighting is essential. (2) Optical aids are recommended.
22.	*LABORATORIES AND TESTING AREAS*					
	General	400	1 or 2	2	19	-
	Calibrated scales, precision mechanisms and instruments	600	1, 2 or 3	1B or 2	n.a.	(1) The use of local lighting is desirable. (2) Care should be taken to avoid unwanted reflections.
	Tasks involving visual display terminals	-	-	-	-	See section 8.2 and Table 9 of this code.

	Type of interior or activities	Maintenance Illuminance lx (Note 1)	Lamp colour appearance group (Note 2)	Lamp colour rendering group (Note 3)	Maximum glare index (Note 4)	Other recommendations
23.	*LAUNDRIES AND DRY CLEANING*					
	Drying room	80	1 or 2	2 or 3	28	See Note 6.
	Drycleaning, bulk machine work	160	1 or 2	2 or 3	28	See Note 6.
	Receiving and dispatch, washing	240	1 or 2	2	25	See Note 6.
	Ironing and pressing	400	2	2	25	See Note 6.
	Sorting and checking	400	2	1B	25	See Note 6.
	Mending and spotting	600	2	1B	25	(1) The use of local lighting is desirable. (2) See Note 6.
24	*LEATHER MANUFACTURING*					
	Vats	160	1 or 2	2	28	See Note 6.
	Cleaning, tanning, stretching, cutting, fleshing and stuffing	240	1 or 2	2	28	See Note 6.
	Finishing and scarfing	240	1 or 2	2	25	See Note 6.
	Pressing and winding	400	2	2	22	See Note 6.
	Cutting, scarfing, sewing	600	1, 2 or 3	1B or 2	19	(1) The use of local lighting is desirable. (2) Directional lighting may be useful.
	Grading and matching	800	2 or 3	1B	n.a.	The use of local lighting is recommended.
25.	*MEATWORKS (ABATTOIRS)*					
	Slaughtering	160	1 or 2	2	28	See Note 6.
	Boning, cleaning, cooking, grinding, canning, packing and cutting	400	1 or 2	2	22	-
	Inspection	600	1, 2 or 3	1B or 2	n.a.	The use of local lighting is desirable.

	Type of interior or activities	Maintenance Illuminance lx (Note 1)	Lamp colour appearance group (Note 2)	Lamp colour rendering group (Note 3)	Maximum glare index (Note 4)	Other recommendations
26.	*METAL FORMING AND TREATMENT*					
	Ingot stripping, soaking pits, annealing and heat treatment bays, acid recovery plant	160	1 or 2	2 or 3	28	See Note 6.
	Picking and cleaning bays, roughing mills, cold mills, finishing mills, tinning and galvanizing lines, cut up and rewind lines	160	1 or 2	2	28	See Note 6.
	Wire mills, product finishing, steel inspection and treatment	240	1 or 2	2	25	See Note 6.
	Plate/strip inspection	400	2	1B or 2	22	The use of local lighting is desirable.
	Control platform and pulpits.	-	-	-	-	See Note 8.
27.	*PACKING AND DISPATCH:*					
	Packing and dispatch, casing, wrapping, labelling, filling and stamping					
	(a) Large objects	160	1 or 2	2 or 3	25	See Note 6.
	(b) Medium objects	240	1 or 2	2	22	-
	(c) Small objects	400	1 or 2	2	19	-
28.	*PAINT MANUFACTURE (Note 7)*					
	General	240	1 or 2	2	25	See Note 6.
	Automatic processes	160	1 or 2	2	28	See Note 6.
	Control panels	240	1 or 2	2	n.a.	Care should be taken to avoid veiling reflections from instrument displays.
	Special batch mixing	600	1, 2 or 3	1B or 2	19	The use of local lighting is desirable.

	Type of interior or activities	Maintenance Illuminance lx (Note 1)	Lamp colour appearance group (Note 2)	Lamp colour rendering group (Note 3)	Maximum glare index (Note 4)	Other recommendations
	Visual colour matching	800	3	1A or 1B	19	Special requirements for visual assessment of colour and colour matching.
29.	*PAINT SHOPS AND SPRAY BOOTHS (Note 7)*					
	Dipping, firing, rough spraying	160	1 or 2	2	28	See Note 6.
	Rubbing, ordinary painting, spraying and finishing	240	1 or 2	2	25	See Note 6.
	Fine painting, spraying and finishing	400	2	2	22	-
	Extra-fine painting, spraying and finishing	600	1, 2 or 3	1B or 2	19	The use of local lighting is desirable.
	Inspection, retouching, matching	800	3	1A or 1B	19	The use of local lighting is recommended.
30.	*PAPER MANUFACTURING AND PROCESSING*					
	Pulp mills, preparation plants	160	1 or 2	2	28	See Note 6.
	Paper and board making:					
	(a) General	240	1 or 2	2	25	See Note 6.
	(b) Inspection, sorting	160	1 or 2	3	28	-
	Paper converting processes:					
	(a) General	240	1 or 2	2	25	See Note 6.
	(b) Associated printing	400	1 or 2	2	22	Where ultraviolet radiation is used for curing ink, special care should be taken to avoid exposure of eyes and skin.
31.	*PETROLEUM, CHEMICAL AND PETROCHEMICAL WORKS (Note 7)*					
	Pump and compressor houses	160	1 or 2	3 or 4	n.a.	-
	Process plant with remote control	80	1 or 2	3 or 4	n.a.	-

	Type of interior or activities	Maintenance Illuminance lx (Note 1)	Lamp colour appearance group (Note 2)	Lamp colour rendering group (Note 3)	Maximum glare index (Note 4)	Other recommendations
	Process plant with permanently occupied workstations	160	1 or 2	3 or 4	28	See Note 6.
	Control rooms, measuring stations, control platforms and observation posts	-	-	-	-	See section 8.2 and Table 9 of this code.
32.	*PHARMACEUTICALS AND FINE CHEMICALS MANUFACTURING (Note 7)*					
	Pharmaceutical manufacture: grinding, granulating, mixing, drying, tableting, sterilizing, washing, solution preparation, filling, capping, wrapping, hardening	400	1 or 2	2	22	-
	Fine chemical manufacturing process plant	80	1 or 2	2	28	(1) Supplementary lighting may be needed for maintenance work. (2) See Note 6.
	Fine chemical finishing	600	1 or 2	2	19	-
	Inspection	600	2 or 3	1B	19	-
33.	*PLASTIC PRODUCTS (Note 7)*					
	Automatic plant:					
	(a) With no manual control or occasional manual control	80	1 or 2	3 or 4	28	See Note 6.
	(b) With frequent manual control	160	1 or 2	2 or 3	28	See Note 6.
	Control rooms and control platforms	-	-	-	-	See section 8.2 and Table 9 of this code.
	Non-automatic plant:					
	(a) Mixing, calendering, extrusion	400	1 or 2	2	25	See Note 6.
	(b) Compression, injection, blow moulding: Loading and unloading	240	1 or 2	2	25	See Note 6.
	(c) Sheet fabrication: shaping, trimming, machining, polishing, cementing	400	1 or 2	2	22	-

	Type of interior or activities	Maintenance Illuminance lx (Note 1)	Lamp colour appearance group (Note 2)	Lamp colour rendering group (Note 3)	Maximum glare index (Note 4)	Other recommendations
	(d) Colour matching and assembly	600	1, 2 or 3	1B or 2	19	The use of local lighting is desirable.
	(e) Plasticized cloths inspection	400	1 or 2	1B or 2	19	-
34.	*PLATING SHOPS (Note 10)*					
	Vats and baths	240	1 or 2	2	25	See Note 6.
	Buffing, polishing and burnishing	400	1 or 2	2	22	-
	Fine buffing and polishing	600	1, 2 or 3	1B or 2	19	The use of local lighting is desirable.
	Inspection	-	-	-	-	Special requirements apply.
35.	*PRINTING INDUSTRY (Note 7)*					
	Pre-press area	320	2 or 3	1B	19	Veiling reflections in the material surfaces may be troublesome.
	Illuminated Tables: general lighting	240	2 or 3	1B or 2	19	Facilities should be provided for dimming the general lighting.
	Proof reading	400	2 or 3	1A or 1B	16	-
	Graphic reproduction	320	2 or 3	1A or 1B	22	-
	Colour reproduction and inspection	1,200	3	1A	n.a.	The use of local lighting is essential.
	Printing machine room	240	2 or 3	1B or 2	22	-
	Printed product inspection	800	3	1A	n.a.	The use of local lighting is recommended.
	Binding and finishing operations	320	2 or 3	1B or 2	22	-
	Binding and finishing machine areas	400	2 or 3	1B or 2	n.a.	-
	screen printing	-	-	-		Special conditions apply.

	Type of interior or activities	Maintenance Illuminance lx (Note 1)	Lamp colour appearance group (Note 2)	Lamp colour rendering group (Note 3)	Maximum glare index (Note 4)	Other recommendations
36.	*RUBBER PRODUCTS (Note 7)*					
	Stock preparation, plasticizing, milling	240	2	2	25	See Note 6.
	Calendering, fabric preparation, stock cutting	400	2	2	22	-
	Extruding, moulding, curing	400	2	2	22	-
	Inspection	800	2 or 3	1B or 2	n.a.	The use of local lighting is recommended
37.	*SHEET METAL WORKS AND STRUCTURAL STEEL FABRICATION (Note 11)*					
	General preparation	240	1 or 2	2 or 3	28	(1) The use of local lighting is recommended for marking off. (2) See Note 6.
	Pressing, punching, shearing, stamping, spinning, folding	400	1 or 2	2	22	The use of local lighting is recommended.
	Bench work, scribing, inspection	600	1, 2 or 3	1B or 2	19	(1) The use of local lighting is recommended. (2) Care should be taken to avoid multiple shadows.
	Welding and soldering					
	(a) Gas and arc welding and brazing	160	1 or 2	2	28	See Note 6.
	(b) Ordinary soldering and spot welding	400	1 or 2	2	22	-
	(c) Fine soldering and spot welding	600	1, 2 or 3	1B or 2	n.a.	The use of local lighting is desirable.
	(d) Extra-fine soldering and spot welding	800	2 or 3	1B	n.a.	The use of local lighting is recommended.
38.	*SHOE AND BOOT MANUFACTURE (Note 7)*					
	Sorting, grading, and preparatory work	800	2 or 3	1B	19	(1) The use of local lighting is recommended. (2) Directional lighting may be useful.

	Type of interior or activities	Maintenance illuminance lx (Note 1)	Lamp colour appearance group (Note 2)	Lamp colour rendering group (Note 3)	Maximum glare index (Note 4)	Other recommendations
	Cutting tables and presses	1,200	1, 2 or 3	1B or 2	n.a.	The use of local lighting is essential.
	Bottom stock preparation, lasting, bottoming, finishing	600	1, 2 or 3	1B or 2	19	The use of local lighting is desirable.
	Rubber preparation and cutting works	240	2	2	25	(1) Drying may involve an explosion risk. (2) Appropriate luminaires are necessary. (3) See Note 6.
	Lining, making and finishing	400	2	2	22	-
39.	*SOAP MANUFACTURE*					
	General areas	240	1 or 2	2 or 3	25	See Note 6.
	Control panels	-	-	-	-	See section 8.2 and Table 9 of this code.
40.	*TEXTILE AND FIBRE PROCESSING*					
	General preparation and processing	240	1 or 2	2 or 3	25	See Note 6.
	Spinning, roving, combing, twisting, winding, and similar processes	400	1 or 2	2	22	-
	Healding (drawing-in)	800	2 or 3	1B or 2	n.a.	The use of local lighting is recommended.
	Plain weaving	600	1, 2 or 3	1B or 2	19	The use of local lighting is desirable.
	Fine weaving	800	2 or 3	1A or 1B	n.a.	The use of local lighting is recommended.
	Inspection	1200	3	1A	n.a.	The use of local lighting is essential
41.	*WAREHOUSE (Note 12)*					
	General storage	80	1 or 2	2 or 3	28	See Note 6.
	Storage routinely involving reading tasks	160	1 or 2	2	25	See Note 6.

	Type of interior or activities	Maintenance Illuminance lx (Note 1)	Lamp colour appearance group (Note 2)	Lamp colour rendering group (Note 3)	Maximum glare index (Note 4)	Other recommendations
42.	*WATCH MANUFACTURING OR REPAIR*					
	General lighting for working areas	400	1 or 2	1B or 2	19	-
	Fine processes	600	1, 2 or 3	1A or 1B	19	The use of local lighting is desirable.
	Minute processes	1,600	3	1A	n.a.	(1) The use of local lighting is essential. (2) Optical aids are recommended.
43.	*WOODWORKING, SAWMILLS AND TIMBER PROCESSING PLANT*					
	General	160	1 or 2	2 or 3	28	See Note 6.
	Rough sawing and bench work	240	1 or 2	2	25	See Note 6.
	Sawing, sizing, planing, rough sanding, medium machine and bench work, gluing, milling and manufacturing work	400	1 or 2	2	22	The use of local lighting is recommended.
	Fine bench and machine work, fine sanding, finishing, veneering, grading and inspection	600	1, 2 or 3	1B	n.a.	(1) The use of local lighting is recommended. (2) Directional lighting may be useful.

Notes to Table 8:

No.	Remarks
1	(a) Maintenance illuminance represents a minimum average illuminance which applies at all times through the life of the lighting system. (b) See section 8.1 of this code.
2.	(a) The colour qualities of a near-white lamp are characterized by its colour appearance and its colour rendering capabilities. (b) The colour appearance of a lamp refers to the apparent colour (chromaticity) of the light it emits. It may be described by its correlated colour temperature. (c) See section 4.3 of this code.
3.	(a) The colour qualities of a near-white lamp are characterized by its colour appearance and its colour rendering capabilities. (b) The colour rendering of a light source is the effect of that source on the colour appearance of object compared with their colour appearance under a reference illuminant. (c) See section 4.3 of this code.
4.	See section 4.2 of this code.
5.	Special care need to be taken for machine shops and fitting shops: (a) some obstruction of lighting is likely; (b) the use of local lighting is desirable on machines; and (c) care should be taken to minimise stroboscopic effects on rotating machines.
6.	(a) In applications for which a maximum glare index of 25 or 28 is indicated, it is particularly important to ensure that the luminaires are adequately shielded from the eyes. (b) Even when the lamp has been adequately screened, the luminance of the image of the lamp from the reflectors directed towards the observer should not exceed the appropriate recommended luminance limit for the work area or task. (c) Holes incorporated in luminaires for ventilation or other purposes should be so located or baffled as to prevent direct view of the lamps. This applies especially to luminaires which may be mounted at or below eye-level to provide localised lighting for the task.
7.	Need to protect against explosion.
8.	(a) Health regulations may apply. (b) Luminaires may need to be sealed or enclosed.
9.	(a) Lighting equipment to be suitable for environmental conditions, e.g. temperature, dust, chemical vapours. (b) The use of safety lighting may be required.
10.	(a) Luminaires suitable for a humid, corrosive atmosphere are desirable. (b) Distracting specular reflections may occur from shining surfaces. (c) Consideration should be given to the use of large-area, low-luminance diffusing luminaires.

Table 9 – Recommendations for visual display tasks

	Type of interior or activities	Maintenance illuminance lux	Lamp colour appearance group	Lamp colour rendering group	Maximum glare index	Other recommendations
1.	CONTROL AND MONITORING ROOMS :					
	Intermittently monitored	240	1 or 2	1B or 2	-	Care should be given to minimise unwanted reflections in control and indicating panels and VDU screens.
	Continuously monitored	320	1 or 2	1B or 2	19	
2.	VISUAL DISPLAY TERMINALS					
	Keyboards	160 or 240	1 or 2	1B or 2	16	1) Where poor quality reference material requires a high illuminance, the terminal area illuminance should be raised to the high level stated to avoid excessive contrast between the adjacent area. 2) Where flat screen technology is used, in particular, gas plasma screens or backlit liquid crystal displays, it may be necessary to limit the illuminance as high illuminances can result in significant loss of contrast.
	Background or environment	160 – 600	1 or 2	1B or 2	16	
	Reference materials:					
	Good and/or simple detail	240	1 or 2	1B or 2	16	
	Average detail	320	1 or 2	1B or 2	16	
	Poor and/or fine detail	600	1 or 2	1B or 2	16	

Publications referred to:

1	BS 950 : Part 1 : 1967 (1980)	Specification for artificial daylight for the assessment of colour - Illuminant for colour matching and colour appraisal.
2	CIBSE Publication TM10	
3	SS 263 : -	Luminaires
4	SS CP 38 : 1999	Artificial lighting in buildings

THE SINGAPORE PRODUCTIVITY AND STANDARDS BOARD

The Singapore Productivity and Standards Board (PSB) is a statutory board established in April 1996, with the integration of the functions of the National Productivity Board (NPB) and the Singapore Institute of Standards and Industrial Research (SISIR) and the takeover of the small and medium-sized enterprise (SME) development function from the Economic Development Board (EDB). It is governed by a board of directors comprising representatives from government, employers, trade unions and academia.

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Figure 1.

Figure 2.

Figure 3.

Figure 4.

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